Dimethyl sulfide and biological life on exoplanets.

Bezverkhniy Volodymyr Dmytrovych.

Ukraine, e-mail: bezvold@ukr.net

Dimethyl sulfide on Earth is emitted into the atmosphere only by living organisms. Therefore, the presence of dimethyl sulfide in the atmosphere is sometimes taken as a marker of biological life on exoplanets. Let's discuss this issue from a chemical point of view.

Chemists have studied various chemical processes and their laws very well. A chemical reaction is the assembly of molecules from atoms in accordance with certain laws. Moreover, these laws are well studied (the reaction is similar to assembling Legos).

Of course, new chemical reactions will be discovered, but for modern chemists, chemical reactions are no longer a mystery. Very often new reactions are intuitive, although there are also original options.

Also note that there is no methane in the Earth's atmosphere, only oxygen and nitrogen. If there is methane in the atmosphere on the planet, then the presence of sulfur, in almost any form, in various ways can lead to the synthesis of dimethyl sulfide.

Dimethyl sulfide is an elemental compound (CH_3-S-CH_3). Its synthesis in the laboratory is possible in many ways. For example, from methyl alcohol and hydrogen sulfide (catalyst - aluminum oxide).

$$2CH_3\text{-}OH + H_2S = CH_3\text{-}S\text{-}CH_3 + 2H_2O$$

Or from methyl chloride and potassium sulfide (that is, from methyl halides and metal sulfides):

$$2CH_3\text{-}Cl + K_2S = CH_3\text{-}S\text{-}CH_3 + 2KCl$$

Dimethyl sulfide can also be obtained in the laboratory from methyl mercaptan and methane halides (chlorine, bromine, etc.):

$$CH_3\text{-}S\text{-}H + CH_3\text{-}Br = CH_3\text{-}S\text{-}CH_3 + H\text{-}Br$$

If we theoretically consider the simplest method of synthesis, then for the synthesis of dimethyl sulfide only sulfur and methane are needed. Since the synthesis of dimethyl sulfide from methane and ordinary sulfur under certain conditions is quite possible (you need to select the conditions, that is, temperature, pressure, catalyst, since alkanes are quite inert).

$$2CH_4 + S = CH_3\text{-}S\text{-}CH_3 + H_2$$

But, let me emphasize once again, this is fundamentally possible (there are enough atoms and functional groups), and given the diversity of conditions on the planets, such a synthesis is quite real. Hydrogen is very reactive, and it can further react with various substances, or escape from the planet's atmosphere if the planet does not have enough gravity.

The easiest way to test is to mix methane and sulfur and heat it to a high temperature (preferably in the presence of a catalyst having an activated surface, for example, certain minerals, etc.).

You can also fill a flask with methane, add free sulfur, and start passing an electric discharge through such a flask. It is better that the sulfur is somehow evenly distributed in the methane atmosphere, that is, that there is stirring or rotation of the flask. Under these conditions, the synthesis of dimethyl sulfide is reduced to selecting the necessary reaction conditions.

Methane under the influence of radiation or high temperature (in the planet's atmosphere, lightning, volcanic lava, etc.) will form a methyl radical (the free radical will be represented by "-"):

$$CH_4 = CH_3\text{-} + H\text{-}$$

Further, in the presence of sulfur (free sulfur or bound sulfur, such as sulfur-containing minerals, or active volcanoes, etc.), various reaction mechanisms will lead to dimethyl sulfide.

For example, let's say that under the influence of temperature or an electrical discharge, a homolytic cleavage of the C-H bond in a methane molecule occurs, resulting in the formation of a methyl radical, which further, through a radical mechanism, will lead to the synthesis of dimethyl sulfide.

Here is an example mechanism:

$$CH_3\text{-} + S = CH_3\text{-}S\text{-}$$

$$CH_3\text{-}S\text{-} + CH_3\text{-} = CH_3\text{-}S\text{-}CH_3$$

If such a reaction occurs, a mixture of substances will be formed (methyl mercaptan (CH_3-SH), hydrogen sulfide (H2S), dimethyl disulfide (CH_3-S-S-CH_3), etc.; in organic reactions, as a rule, a mixture of substances is formed, and therefore conditions are selected that maximize the formation of the necessary products).

The above reaction is easy to test in the laboratory. In addition, there are also various ionic mechanisms that can lead to the synthesis of dimethyl sulfide from methane and sulfur, and this will fundamentally change the reaction conditions and starting materials.

The sulfur atom is highly nucleophilic, therefore, when the methyl cation (CH_3+) is formed from methane (at high temperature, electric discharge, in the presence of a catalyst, etc.), the formation of a C-S bond occurs very easily. Moreover, the attack of the methyl cation will also be successful on the sulfur atom, which is in a bound form (various sulfur-containing minerals). Therefore, there are a lot of options for synthesizing dimethyl sulfide, and these reactions will have no relation to biological life (although some organisms can indeed synthesize dimethyl sulfide themselves).

Let me give you a few more examples.

Theoretically, the synthesis of dimethyl sulfide from methyl mercaptan and methyl alcohol is possible (under certain conditions):

$$CH_3\text{-}S\text{-}H + CH_3\text{-}OH = CH_3\text{-}S\text{-}CH_3 + H_2O$$

It is also theoretically possible to synthesize dimethyl sulfide from methyl mercaptan and even methane:

$$CH_3\text{-}S\text{-}H + CH_4 = CH_3\text{-}S\text{-}CH_3 + H_2$$

Under certain conditions, the decomposition of methyl mercaptan will also lead to the formation of dimethyl sulfide:

$$2CH_3\text{-}S\text{-}H = CH_3\text{-}S\text{-}CH_3 + H_2S$$

In general, there are really many options for the synthesis of dimethyl sulfide.

In conclusion, I note that the presence of dimethyl sulfide in decent quantities in the atmosphere of exoplanets only means that both methane and sulfur (in any form) are present on the planet in decent quantities. Or there is active volcanic activity (during volcanic eruptions, volcanic gases often contain free and bound sulfur, methane and other gases).

Consequently, there can be no question of any biological life on such a planet (since there is methane in the atmosphere).

This means that dimethyl sulfide cannot be a marker of biological life on exoplanets.